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REPORT #2

Environmental Stability Testing of a Coated, Elastomeric Dental Ribbon

Final Report

Gary J. Shemaka *William W. Tenero



Cooper Dental Products, Portland, Oregon *Spring borne Industries, Enfield, Connecticut

September, 1979

Supported by

U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND Fort Detrick, Frederick, Maryland 21701

Contract No. DAMD 17-78-C-8084

Cooper Laboratories 110 E. Hanover Avenue Cedar Knolls, New Jersey 07927

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SECURITY CLASSIFICATION OF THIS PAGE (When Dets Entered) READ INSTRUCTIONS REPORT DOCUMENTATION PAGE BEFORE COMPLETING FORM I. REPORT NUMBER ENVIRONMENTAL STABILITY TESTING OF A COATED, 0ct**≪** Final) ELASTOMERIC DENTAL RIBBON . Sep CONTRACT OR GRANT NUMBER(A) Gary J. Shemaka William W. Tenero DAMD17-78-C-8684 9. PERFORMING ORGANIZATION NAME AND ADDRESS Cooper Laboratories V 110 E. Hanover Avenue 61102A**7**3\$1611**\$**2B\$**\$**6 Cedar Knolls, NJ 07927 11. CONTROLLING OFFICE NAME AND ADDRESS 12. REPORT DATE US Army Medical Research and Development Comman 1/ Septembers 2079 Fort Detrick NUMBER OF PAGES Frederick, MD 21701
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and 120° Fahrenheit. Yield Strengths were 3730, 2170, 1130 and 1100 (p.s.i.) respectively. Break Strengths were 4150, 5030, 5260 and > 4500 (p.s.i.) respectively. Percent Elongations at breakage were 540, 640, 600 and > 700 ~

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percent) respectively. Modulus were 5.0, 0.18, 0.14 and 0.08 (x10⁵ p.s.i.) respectively. The Tensile Impact Strengths were 180, 520, 580 and 720 (ft. -1bs./in.²) respectively.

The dental tape was placed in circulating air ovens at room temperature as a control, at 1600F with 90% relative humidity, at 1940F and 2300F for six and twelve weeks. After exposure, the specimens were removed and allowed to condition for a minimum of 40 hours at 730F with 50% relative humidity. They were again tested for Tensile properties and Tensile Impact Strength. The Yield Strengths were 1130, 1630, 1830, 1380, 1390 and 2200 (p.s.i.) respectively. The Break Strengths were 5260, 4930, 3910, 2300, 1660 and 2700 (p.s.i.) respectively. The Percent Elongations at breakage were 600, 1060, 850, 790, 56 and 590 (percent) respectively. The Modulus were 0.14, 0.13, 0.14, 0.14, 0.13 and 0.71 (x105 p.s.i.) respectively. The Tensile Impact Strengths were 580, 331, 220, 500, 310 and 13 (ft. -1bs./in²). Samples that were placed in the oven at 2300F for twelve weeks and samples at 2660F for 1, 3, 6 and 12 weeks were found too brittle to test.

No blocking was observed at -60, 73 and 160°F for a maximum of one month duration at 0.5 p.s.i. pressure. Little dimensional changes were noted at 160°F with 90% relative humidity, 194°F and 230°F, up to twelve weeks. Samples exposed at 266°F for six weeks were too brittle to be tested.

In conclusion, the coated elastomeric tape was found acceptable for use in a temperature range of 0 to 120°F. Due to high Modulus and low Tensile Impact Strength, the product will not function at -40°F. It was found suitable for storage at 194°F and 160°F with 90% relative humidity for twelve weeks. When stored at 230°F, the material proved too brittle for its intended use.

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Summary:

A coated, elastomeric dental ribbon developed by Dr. Paul Jaffe with Cooper Laboratories was taken through a series of physical tests at various environmental conditions to determine its suitability for military application. Tensile properties and Tensile Impact Strengths were determined at -40, 0, 73 and 120°Fahrenheit. Yield Strengths were 3730, 2170, 1130 and 1100 (p.s.i.) respectively. Break Strengths were 4150, 5030, 5260 and >4500 (p.s.i.) respectively. Percent Elongations at breakage were 540, 640, 600 and >700 (percent) respectively. Modulus were 5.0, 0.18, 0.14 and 0.08 (x 10 p.s.i.) respectively. The Tensile Impact Strengths were 180, 520, 580 and 720 (ft.-lbs./in.²) respectively.

The dental tape was placed in circulating air ovens at room temperature as a control, at 160°F with 90% relative humidity, at 194°F and 230°F for six and twelve weeks. After exposure, the specimens were removed and allowed to condition for a minimum of 40 hours at 73°F with 50% relative humidity. They were again tested for Tensile properties and Tensile Impact Strength. The Yield Strengths were 1130, 1630, 1830, 1380, 1390 and 2200 (p.s.i.) respectively. The Break Strengths were 5260, 4930, 3910, 2300, 1660 and 2700 (p.s.i.) respectively. The Percent Elongations at breakage were 600, 1060, 850, 790, 560 and 590 (percent) respectively. The Modulus were 0.14, 0.13, 0.14, 0.14, 0.13 and 0.71 (x 10 p.s.i.) respectively. The Tensile Impact Strengths were 580, 331, 220, 500, 310 and 13 (ft.-lbs./in.²). Samples that were placed in the oven at 230°F for twelve weeks and samples at 266°F for 1, 3, 6 and 12 weeks were found too brittle to test.

No blocking was observed at -60, 73 and $160^{\circ}F$ for a maximum of one month duation at 0.5 p.s.i. pressure. Little dimensional changes were noted at $160^{\circ}F$ with 90% relative humidity, $194^{\circ}F$ and $230^{\circ}F$, up to twelve weeks. Samples exposed at $266^{\circ}F$ for six weeks were too brittle to be tested.

In conclusion, the coated elastomeric tape was found acceptable for use in a temperature range of 0 to 120°F. Due to high Modulus and low Tensile Impact Strength, the product will not function at -40°F. It was found suitable for storage at 194°F and 160°F with 90% relative humidity for twelve weeks. When stored at 230°F, the material proved too brittle for its intended use.

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Body of the Report:

Title: Environmental Stability Testing of a Coated, Elastomeric

Ribbon

Objective:

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To define and monitor the rate of degradation of various physical properites of a coated, elastomeric dental ribbon under several thermal and humidifing conditions. The physical properties investigated were Yield Strength, Break Strength, Percent Elongation at Breakage, Modulus, Tensile Impact Strength, Blocking Characteristics and Dimensional Changes.

Methods and Materials:

Cooper Laboratories supplied 500 coated Hytrel strips measuring 4 x 3/16 inches. Springborne Industries supplied the necessary conditioning chambers and instron units to perform the following tests:

A. Tensile Properties at 120°F, 73°F, 0°F, and -40°F A.S.T.M D882 and D759 Method A

Apparatus: Instron Tensile Tester TM Grip Separation: 1.0 in. Str., 2.0 in. Mod. Gauge Length: 1.0 in. Str., 2.0 in. Mod.

Crosshead Speed: 20.0 in/min. Str., 2.0 in./min. Mod. Chart Speed: 5.0 in./min. Str., 20 in./min. Mod.

Load Range: 0-10 lbs. Str., 0-1 lb. Mod.

B. Tensile Impact Strength at 120°F, 73°F, 0°F, and -40°F A.S.T.M. D759 and D&R Spec

The strip specimens were tested for Tensile Impact Strength using a modified Baldwin Impact Tester. A specific fixture holds the specimen at 90° to the impact pendulum. A test gauge-length of 0.50 inches was used. The load capacity of the appartus is 2 ft. -lbs.

- C. Degradation of Tensile Properties and Tensile Impact Strength when exposed at 194°F, 230°F, 266°F and 160°F at 90% Relative Humidity for six and twelve weeks.

 A.S.T.M. D794 and E145
- D. .Blocking Characteristics at 160°F, 73°F and -60°F .FTMS 101B method 3003 Procedure A

The specimens were tested dull side to dull side, shiny side to shiny side and dull side to shiny side. Periodically the specimens were checked for any sign of blocking by removing the 0.5 psi test load from the stack and pulling the sheets apart.

the second second

E. Dimensional changes when exposed at 194 F, 230 F, 266 F and 160 F at 90% Relative Humidity for six and twelve weeks. The widths were measured with a machinist's micrometer (to 0.001 inch) and the lengths were measured with a steel ruler (to 0.01 inch).

**Conditioning

Specimens tested at temperatures above and below room temperature were conditioned for a minimum of one hour at the test temperature. Aged specimens were conditioned for 40 hours at 73°F and 50% Relative Humidity prior to testing.

Results:

A Tensile Properties at Various Temperatures

| Table | One: | Yield | Strength |
|-------|------|-------|----------|
| | | | |

| Test Temperature (F) | Averaged Yield Strength (PSI) | A Percent from Control |
|----------------------|----------------------------------|------------------------|
| -40 | 3730 | 230 |
| 0 | 2170 | 92 |
| 73 | 1130 | 0 |
| 120 | <pre>\ 1100</pre> | -2.7 |

Table Two: Break Strength

| Test Temperature (F) | Averaged Break Strength (PSI) | A Percent from Control |
|-------------------------|----------------------------------|------------------------|
| -40 | 4150 | -21.1 |
| Ö | 5030 | -4.3 |
| 73 | 5260 | 0 |
| 120 | >4500 | N/A |

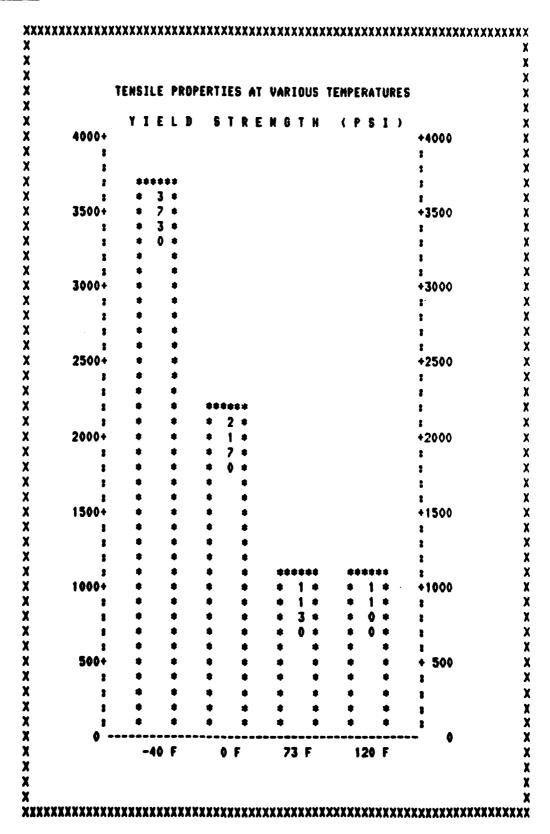
Table Three: Percent Elongation at Breakage

| Test Temperature (f) | Averaged % Elongation at Breakage (%) | A Percent from Control |
|----------------------|---|------------------------|
| -40 | 540 | -10 |
| Ō | 640 | 6.7 |
| 73 | 600 | 0 |
| 120 | >700 | N/A |

Table Four: Modulus

| Test Temperature (F) | Averaged Modulus (10 ⁵ p.s.i.) | A Percent from Control |
|----------------------|---|------------------------|
| -40 | 5.0 | 3471 |
| 0 | .18 | 28.5 |
| 73 | .14 | 0 |
| 120 | .08 | -42.9 |

Graph One:



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Graph Two:

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| 3500 · | | -4 | 0 | F | | 0 | F | | 73 | F | | 120 | F | 3500 |
|-------------|------|--------|----|------|-----|-----|--------|-------|--------|--------|------|--------|-----|----------------|
| 8 | |)) | | • | • | | • | | | • | ^ | | • | 1 |
| 3700+ | • | • | | • | • | | * | • | | • | • | | • | +37 0 0 |
| | • |) | | • | • | | • | * | | • | • | | • | 1 |
| 1 | • | , } | | * | • | | | * | | * | • | | • | : |
| 3900+ | • | • | | • | | | • | | | • | | | • | +3900 |
| | - 7 | | 0 | • | | | | * | | * | • | | • | • |
| | • |) | 1 | * | * | | | * | | | ^ | | • | : |
| 4100+ | • | • | 4 | * | • | | • | | | | • | | • | +4100 |
| 3 | • | ** | ** | * | • | | • | * | | • | • | | • | 3 |
| 3 | | | | | * | | * | * | | | ^ | | ^ | : |
| 4300+ | | | | | • | | • | | | * | ^ | 0 | • | +4300 |
| : | | | | | * | | * | * | | | • | 0 | ^ | • |
| : | | | | | * | | # # | * | | # # | | 4 5 | ^ | t |
| 4500+ | | | | | * | | | • | | | | | | +4500 |
| : | | | | | | | * | | | | | | | 1 |
| : | | | | | * | | * | * | | * | | | | • |
| 4700+ | | | | | * | | * | * | | * | | | | +4700 |
| | | | | | | | * | * | | * | | | | ! |
| : | | | | | | • | * | | | * | | | | : |
| 4900+ | | | | | | 0 | * | * | | * | | | | +4900 |
| **** | | | | | | 0 | * | * | | • | | | | 1 4000 |
| 1 | | | | | | 5 | * | * | | • | | | | 3 . |
| 1 | | | | | ** | **1 | ** | * | 0 | * | | | | 1. |
| \$ 5100+ | | | | | | | | * | 2 | | | | | : +5100 |
| : | | | | | | | | | 5 | * | | | | : |
| 3 | | | | | | | | | *** | ** | | | | : |
| 5300+ | | | | | | | | | | | | | | * +5300 |
| | | | | | | | | | | | | | | 3 |
| 1 | | | | | | | | | | | | | | : |
| 5500+ | • | • | | m n | • | • | | | , | ** | ` ' | • | • / | +5500 |
| | | | E | A K | S | 1 | RI | E N (| G T | ш | | , c | 1) | |
| | TENS | IL | E | PROF | ERT | IE | 5 A1 | T VAI | RIO | US 1 | ENPE | ERAT | URE | 5 |
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Graph Three:

| 500 | | -(| 10 | F | | 0 | F | | 73 | F | | 120 | F | 300 |
|------|----------|--------|----|------------|-------|------------|--------|----------|----------|-------|-------|------------|----------|-----------|
| | | ; 1 | V | * | | • | • | • | • ! | • | | <u>-</u> - | <u>.</u> | ; ; |
| 1 | • | 1 | 4 | • | • |) | • | • | , | • | | | - | : |
| 530 | - | 1 | 5 | • | • | 1 | • | • | | | • | | • | +530 |
| | • | | *1 | | • | , I | • | • | | * | • | | • | : |
| | : | | | | • | | * | | | # | • | | • | : |
| 5604 | • | | | | • | | • | • | | | • | | | +560 |
| i | 3 | | | | | | • | • | | • | ^ | | • | 1 |
| • | , 1 | | | | | | • | | 0 | • | • | | • | 1 |
| 5904 | | | | | * | | | * | 0 | | ^ | | • | 1 |
| E004 | • | | | | | | ¥ | ₩ | +∓4 1 | ** | | | • | : +590 |
| 1 | | | | | | | • | | *** | | _ | | | |
| 1 | | | | | • | | | | | | • | | | : |
| 620+ | • | | | | | 0 | * | | | | • | | • | +620 |
| : | <u>'</u> | | | | | 4 | | | | | • | | •. | : |
| | | | | | # | ¥ ¥ ¥ A | ** | | | | • | | • | : |
| 650+ | • | | | | • | | ** | | | | • | | • | 1030 |
| 154 | | | | | | | | | | | - | | • | : +650 |
| 1 | | | | | | | | | | | • | | | : |
| 1 | | | | | | | | | | | • | | | : |
| 480+ | | | | | | | | | | | ^ | 0 | • | +680 |
| 1 | | | | | | | | | | | • | 0 | ^ | : |
| : | | | | | | | | | | | • | 7 | • | • |
| 710+ | | | | | | | | | | | ^ ^ | | | +710 : |
| | | | | | | | | | | | | | | ‡ 471∆ |
| 2 | | | | | | | | | | | | | | 1. |
| : | | | | | | | | | | | | | | : |
| 740+ | | | | | | | | | | | | | | +740 |
| | | | | | | | | | | | | | | : |
| | | | | | | | | | | | | | | : |
| 770+ | | | | | | | | | | | | | | 1 |
| | | | | | | | | | | | | | | : +770 |
| | | | | | | | | | | | | | | • |
| 3 | | | | | | | | | | | | | | : |
| 800+ | | | | • | LLUM | OF I | TON | # I | -46 | | 76 | | | +800 |
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| | TENSI | LE | f | RO | PERT | IES | AT | VAR | 10l | 15 TE | MPE | (AT | UKES | j |
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Graph Four:

Waster !

| 1.750+ |). 00 0 - | | 40 F | 0 F | 73 F | 120 F | 0.000 |
|--|---|----------|----------------|------------|-----------|------------|--------|
| # 6 B U L U S (1 0 * * 5 P S I) 5.000 | 1 | • | • | ***** | ***** | ***** | 1 |
| # 6 B U L U S (1 0 * * 5 P S I) 5.000 | - | • | • | | 4 | 8 | 1 250 |
| # 0 D U L U S (1 0 * * 5 P S I) 5.000 | 0.500 + | • | • | 1 | 1 | • | +0.500 |
| HOBULUS (10 * * 5 P S I) 5.000 5.000 * | _ | • | • | • | • | • | 1 |
| HOBULUS (10 * * 5 P S I) 3.000 * ****** 5 | 0.750+ | • | • | | | | |
| HOBULUS (10 * * 5 P S I) 3.000 * ****** 5 * * * * * * * * * * * * * * | • | • | • | | | | |
| # 0 B U L U S (1 0 * * 5 P S I) 3.000 | | • | • | | | | |
| # 0 D U L U S (1 0 * * 5 P S I) 3.000 | | • | • | | | | +1.250 |
| # 0 B U L U S (1 0 * * 5 P S I) 5.000 | - | • | • | | | | |
| | 1.500+ | | • | | | | |
| # 0 B U L U S (1 0 * * 5 P S 1) 5.000 | | • | • | | | | |
| # 0 B U L U S (1 0 * * 5 P S 1) 5.000 | _ | • | | | | | - |
| HOBULUS (10 * * 5 P S I) 3.000 * ***** | | • | • | | | | |
| | - | | • | | | | - |
| HOBULUS (10 * * 5 PSI) 5.000 * ***** | | • | | | | | +2.250 |
| | - | | • | | | | • |
| # 0 B U L U S (1 0 * * 5 P S I) 5.000 | 2.500+ | | • | | | | +2.500 |
| # 0 B U L U S (1 0 * * 5 P S I) 5.000 1.750+ 1.500+ 1.500+ 1.000+ 1.750+ 1.000+ 1.750+ 1.000+ 1.750+ 1.000+ 1.750+ 1.000+ 1.750+ 1.000+ 1.750+ 1.000+ 1.750+ 1.00 | _ | • | | | | | 1 |
| HOBULUS(10 * * 5 P S I) 5.000 | 2.750+ | | | | | | +2.750 |
| HOBULUS(10 * * 5 P S I) 5.000 | 1 | • | • | | | | 13.000 |
| # 0 B U L U S (1 0 * * 5 P S I) 5.000 5.000 1.750+ 1.500+ 1.500+ 1.500+ 1.750+ 1.500+ 1.750+ 1.500+ 1.750+ 1.500+ 1.750+ 1.500+ 1.750+ 1.500+ 1.750+ 1.500+ 1.750+ 1.500+ 1.750+ 1.500+ 1.750+ 1.500+ 1.750 | • | • | • | | | | |
| HOBULUS(10 * * 5 P S I) 5.000 + ***** | | - | ∓ | | | | |
| HOBULUS(10 * * 5 P S I) 5.000 + ***** | - | | | | | | |
| HOBULUS(10 * * 5 P S I) 5.000 * **** | | • | • | | | | +3.500 |
| HOBULUS(10 * * 5 P S I) 5.000 + ***** | | | • | | | | - |
| HOBULUS (10 * * 5 P S I) 5.000 + ***** | 3.750+ | | • | | | | - |
| HOBULUS (10 * * 5 P S I) 5.000 + ***** | | | | | | | |
| HOBULUS (10 * * 5 P S I) 5.000+ ***** | 4.000+ | • | | | | | - |
| HOBULUS (10 * * 5 P S I) 5.000 + ***** | | | | | | | |
| HOBULUS (10 * * 5 P S I) 5.000 + ***** | 4.250+ | | • | | | | |
| HOBULUS (10 * * 5 P S I) 5.000+ ***** | | • | 0 = | | | | |
| HOBULUS(10 * * 5 P S I) 5.000 + ***** +5.000 2 * 5 * 2 1.750 + . * +4.750 | - | • | 0 = | | | | - |
| HOBULUS (10 * * 5 P S I) 5.000+ ***** +5.000 2 * 5 * 2 | | ∓ | . - | | | | |
| HOBULUS(10 * * 5 P S I) 5.000+ ***** +5.000 | - | • | 2 * | | | | |
| HODULUS (10 * * 5 P S I) | 5.000+ | ** | **** | | | | +5.000 |
| TENSILE PROPERTIES AT VARIOUS TEMPERATURES | | | H O D | ulus (| 10 * * 5 | PSI) | |
| TENSILE PROPERTIES AT VARIOUS TEMPERATURES | | | | | | | |
| | | TENSI | LE PR | OPERTIES A | T VARIOUS | EMPERATURE | S |
| | | | | | | | |

B Tensile Impact Tests at Various Temperatures

Table Five: Tensile Impact Strength

| Test Temperature (F) | Averaged Tensile Impact Strength (ftlbs./in. ²) | A Percent from Control |
|---------------------------------------|---|-------------------------------------|
| -40 0 73 | 180 520 580 | -68.9 -10.3 |
| 120 | 720 | 24.1 xxxxxxxxxxxxxxxxxxxxx x |
| X X Graph Five X 1E | NSILE IMPACT TEST AT VARIU | X X US TEMPERATURES X X |
| X X X 800+ | TENSILE IMPACT STRENGTH(F | T.LBS./IN++2) X +800 X |
| X : X : X : | | 2 X 2 X . 2 X |
| X : | | ***** |
| X : X : X : | | * 0 * s X * * : X |
| X 600+ X : X : | *** | * * +600 X ** * * 2 X |
| , , , , , , , , , , , , , , , , , , , | * B | * * * : X * * * : X |
| , , , , , , , , , , , , , , , , , , , | * 2 * * | * * * * X * * * * X |
| X 1 X 400+ X 2 | | * * * * X * * * +400 X |
| X : X : X : | | * * * * X * * * * X |
| х х х | | * * * * : X * * * * : X |
| . X 200+ | | * * * * X * * * * X * * * * * * * X |
| X : | ****** * * * * * * * * * * * * * * * * | * * * * X * * * * X |
| X : X : X : | | * * * * X * * * * X |
| X : X : X : | | * * * * X |
| ¥ | | |

Results:

C Tensile Properties at Various Thermal and Moisture Exposures

Table Six: Yield Strength

| • | Expos Condi | ure tions | | Averaged Yie Strength (PS: | _ | | Percent Control |
|--------|----------------|---------------|-------------------------|-------------------------------------|--------|--------------|--------------------|
| Contro | ol | | | 1130 | | | 0 |
| 160°F | , 90% | R.H., 6 12 | wks wks | 1630 1830 | | | 44.2 61.9 |
| 194°F | | | wks wks | 1380 1390 | | | 22.1 23.0 |
| 230°F | | | wks wks | 2200 Too britt | tle to | | 94.7 |
| 266°F | | 3 6 | wk wks wks wks | Too britt Too britt Too britt | tle to | test test | ٠ |

Table Seven: Break Strength

| Exposure Conditions | | Averaged Break Strength (PSI) | \triangle from | Percent Control |
|---------------------|------------------|---|------------------|--------------------|
| Control | | 5260 | | 0 |
| • | wks wks | 4930 3910 | | -6.3 -25.7 |
| | wks wks | 2300 1660 | | -56.3 -68.4 |
| - | wks wks | 2700 Too brittle | to test | -48.7 |
| 3 6 | wk wks wks | Too brittle Too brittle Too brittle | to test | |
| <i>;</i> 12 | wks | Too brittle | to test | • |

The state of the s

Results:

<u>C</u> Tensile Properties at Various Thermal and Moisture Exposures
<u>Table Eight: Percent Elongation at Breakage</u>

| • | Expos Cond: | sure ition | | <u>E1</u> | ongai | tion at 1 | Brea | akage | △ from | Percent Control |
|--------|----------------|---------------|---|-------------------------|------------|--|----------|--------------|-----------|--------------------|
| Contro | ol , | | | | | 600 | | 0 | | |
| 160°F | , 90% | R.H., | | wks wks | | 1060 850 | | | | 76.7 41.7 |
| 194°F | | | _ | wks wks | | 7 90 560 | | | • | 31.7 -€.7 |
| 230°F | | | | wks wks | Too | 590 brittle | to | test | | 1.7 |
| 266°F | | | 3 | wk wks wks wks | Too Too | brittle brittle brittle brittle | to to | test test | | |

Table Nine: Modulus

| | | sure lition | | | Average | ed Moduli | <u>us</u> | | Δ from | Percent Control |
|--------|-----|----------------|---|-------------------------|------------|--|-----------|--------------|---------------|--------------------|
| Contro | 1 | | | | | 0.14 | | | | 0 |
| 160°F, | 90% | R.H., | | wks wks | | 0.13 0.14 | | | | -7.1 0 |
| 194°F | | | | wks wks | | 0.14 0.13 | | | | 0 -7.1 |
| 230°F | | | | wks wks | Too | 0.71 brittle | to | test | 1 | 407.1 |
| 266°F | | | 3 | wk wks wks wks | Too Too | brittle brittle brittle brittle | to to | test test | | |

The second second second second

Graph Six

| | . •• | ERI | • | | 16 | 0 1 (| ט ד פ | | - 1 | K P O | | • | |
|--------------|------|-----|------------------|--------|-----|-------|-------|----------|-----|----------|----------|----------|---------------|
| | | Y | IE | L B | s T | RF | N 8 1 | 1 H | (P | s i |) | | |
| 2500.00+ | | • | - - (| _ • | - • | | 🖝 (| . 44 | • • | - • | - | | +2500.00 |
| 2400.00+ | | | | | | | | | | | | | : +2400.00 |
| 2300.00+ | | | | | | | | | | | | | : +2300.00 |
| 1 | | | | | | | | | | | | | 8 |
| 2200.00+ | | | | | | | | | | | XXX | XXX X | +2200.00 : |
| 2100.00+ | | | | | | | | | | | X | X | +2100.00 |
| 2000.00+ | | | | | | | | | | | X | X | +2000.00 |
| 1700.00+ | | | | | | | | | | | X | X | : +1900.00 |
| 1800.00+ | | | | | XX | XXX | | | | | X | 'Χ | : |
| 1800.007 | | | | | X | X | | | | | X | X | +1800.00 1 |
| 1700.00+ | | | XX | XXX | X | X | | | | | X | X X | +1700.00 |
| 1400.00+ | | | X | X | X | X | | | | | X | X | +1600.00 |
| 1500.00+ | | | X | X X | X | X | | | | | X | X | : +1500.00 |
| 1 | | | X | X | X | X | uv. | | ••• | | X | X | |
| 1400.00+ | | | X | X X | X | X | X | XXX X | XXX | KXX X | X | X | +1400.00 ; |
| 1300.00+ | | | X | X | X | X | X | X | X | X | X | X | +1300.00 |
| 1200.00+ | 2000 | | X | X | X | X | X | X | X | X | X | X | +1200.00 |
| 1100.00+ | XX | XXX | X | X X | X | X | X | X | X | X | X | X | ; +1100.00 |
| 1000.00+ | X | X | X | X | X | X | X | X | X | X | X | X | # +1000.00 |
| * | X | X | X | X | X | X | X | X | X | X | X | X | 3 |
| 700.00+ | X | X | X | X | X | X | X | X | X | X | X | X | + 900.00 |
| 800.00+ | X | X | X | X | X | X | X | X | X | X | X | X | + 800.00 |
| 700.00+ | X | X | X | X | X | X | X | X | X | X | X | X | 1 + 700.00 |
| t 400.00+ | X | X | X | X | X | X | X | X | X | X | X | X | : + 400.00 |
| 8 | X | X | X | X | X | X | X | X | x | X | X | X | |
| 500.00 | | | | | | | ••••• | | | | | | 500.00 |

| Bar | Exposure Condition | Value |
|----------------------------|--|--|
| 1 2 3 4 5 6 | Control 160°F, 90° R.H., 6 wks 12 wks 6 wks 12 wks 230°F 6 wks | 1130 1630 1830 1380 1390 2200 |

Graph Seven

Section Control

こうかいちょうている これらいのをおのからないなどのないできます いからからいれるない おおれている

| 888 4 444 | | 1 | RE | A K | \$ | I R E | N G | T H | (P S I) | | | ARRAC AA |
|-------------------|-----|--------|----|-----|----|-------------|-------------|-----|-----------|----------|-----|-------------------|
| 5500.00+ | | | | | | | | | | | | +5500.00 |
| | | | | | | | | | | | | 1 |
| | XX. | XXX | | | | | | | | | | |
| | X | X X | | | | | | | | | | |
| 5000.00+ | Ŷ | Ŷ | | | | | | | | | | +5000.00 |
| 3000.00 | x | Ŷ | 44 | XXX | | | | | | | | *3000.00 |
| • | x | X | X | X | | | | | | | | • |
| • | Ŷ | x | x | Ŷ | | | | | | | | • |
| • | x | x | x | x | | | | | | | | • |
| 4500.00+ | Ŷ | x | x | x | | | | | | | | +4500.00 |
| 1 | x | x | x | x | | | | | | | | ; |
| | X | X | X | X | | | | | | | | : |
| 3 | X | X | X | X | | | | | | | | 1 |
| 1 | X | X | X | X | | | | | | | | 1 |
| 4000.00+ | X | X | X | X | | | | | | | • | +4000.00 |
| 8 | X | X | X | X | XX | XXX | | | | | | * |
| * | X | X | X | X | X | X | | | | | | : |
| : | X | X | X | X | X | X | | | | | | : |
| | X | X | X | X | X | X | | | | | | • |
| 3500.00+ | X | X | X | X | X | X | | | | | | +3500.00 |
| * | X | X | X | X | X | X | | | | | | 1 |
| : | X | X | X | X | X | X | | | | | | • |
| | X | X | X | X | X | X | | | | | | : |
| * | X | X | X | X | X | X | | | | | | |
| 3000.00+ | X | X | X | X | X | X | | | | | | +3000.00 |
| | X | X | X | X | X | X | | | | | | • |
| | X | X | X | X | X | X | | | | . | | • |
| | X | X | X | X | X | X | | | | | XXX | i . |
| 2500.00+ | X | X | X | X | X | X | | | | X | X | +2500.00 |
| ZJVV. V V* | X | X | X | X | X | X | | | | X | X | 4 2309.9 0 |
| | X | X | x | X | X | X | XXX | (YY | | X | X | • • |
| | Ŷ | X | X | X | x | x | X | X | | X | X | • |
| • | Ŷ | Ŷ | Ŷ | Ŷ | Ŷ | Ŷ | Ŷ | Ŷ | | Ŷ | â | • |
| 2000.00+ | Ŷ | x | Ŷ | x | Ŷ | Ÿ | Ŷ | x | | x | X | +2000.00 |
| 1 | Ŷ | x | X | X | Ÿ | X | Ŷ | x | | x | x | 1 |
| | x | x | X | x | x | X X X | X X X | x | | X | X | į |
| | X | x | X | X | X | X | X | x | | X | x | ĺ |
| _ | X | X | X | | X | | X | X | XXXXX | X | | _ |

| Bar | Exposure Condition | Value |
|-------------|---|----------------------|
| 1 2 3 | Control 160°F, 90% R.H., 6 wks 12 wks | 5250 4930 3910 |
| 4 | 194°F 6 wks | 2300 |
| 5 6 | 230°F 12 wks | 1600 2700 |

Graph Eight

| 4865 | 2 E L | . O N | 6 A | 7 1 | D N | A T | • | R E | KA | GE | | .4865 |
|---------------|------------|-------|-----|-----|-----|-----|-----|-----|----|-----|-----|----------|
| 1200+ | | | | | | | | | | | | +1200 |
| | | | | | | | | | | | | 1 |
| • | | | | | | | | | | | | |
| • | | | | | | | | | | | | • |
| 1100+ | | | | | | | | | | | | +1100 |
| 3 | | | | | | | | | | | | 1 |
| 8 | | XX | XXX | | | | | | | | | 1 |
| 1 | | X | X | | | | | | | | | |
| 1 | | X | X | | | | | | | | | 1 |
| 1000+ | | X | X | | | | | | | | | +1000 |
| | | X | X | | | | | | | | | |
| 1 | | X | X | | | | | | | | | 2 |
| | | X | X | | | | | | | | | 1 |
| 700+ | | X | X | | | | | | | | | 1 |
| 700+ | | X | X | | | | | | | | | + 900 |
| • | | Ŷ | x | XX | XXX | | | | | | | * |
| i | | X | X | X | X | | | | | | | 2 |
| , | | X | X | X | X | | | | | • | | • |
| 800+ | | X | X | X | X | XX | XXX | | | | | + 800 |
| 1 | | X | X | X | X | X | X | | | | | |
| 1 | | X | X | X | X | X | X | | | | | • |
| 1 | | X | X | X | X | X | X | | | | | 1 |
| 700+ | | X | X | X | X | X | X | | | | | 1 |
| / V V+ | | X | X | X | X | X | X | | | | | + 700 |
| • | | x | x | Ŷ | x | x | Ŷ | | | | | • |
| 1 | | x | x | Ŷ | x | â | x | | | | | • |
| 1 | | X | X | X | x | x | x | | | | | • |
| 400+ | XXXXX | X | X | X | X | X | X | | | XXX | (XX | + 400 |
| | X X | X | X | X | X | X | X | | | X | X | |
| 3 | X X | X | X | X | X | X | X | XXX | | X | X | 1 |
| 1 | X X | X | X | X | X | X | X | X | X | X. | , X | 2 |
| 1 | XX | X | X | X | X | X | X | X | X | X | X | 1 |
| 200+ | XX | X | X | X | X | X | X | X | X | X | X | + 500 |
| • | X X X X | X | X | X | X | X | X | X | X | X | X | 8 |
| • | x x | Ŷ | Ŷ | Ŷ | X | â | â | x | x | X | X | • |
| • | X X | î | î | Ŷ | x | x | x | x | x | x | Ŷ | • |

| Bar | Exposure Condition | <u>Value</u> |
|--------|---|-----------------------------------|
| 123456 | Control 160°F, 90° R.H., 6 wks 194°F 12 wks 230°F 6 wks | 600 1060 1050 750 590 |

Graph Nine

| | | | . | | | _ | | | | | | | |
|-------|-----|------------------|-------------|------------------|-------------|--------|------------------|-------------|-----|------------|-------------|-----|----------|
| 0.80+ | | | W 0 1 | 9 8 6 | . U S | (| 1 0 | • • ; | 5 P | S I |) | | +0.80 |
| | | | | | | | | | | | | | 1 |
| 8 | | | | | | | | | | | | | 1 |
| 1 | | | | | | | | | | | | | 3 |
| | | | | | | | | | | | XX | XXX | |
| 0.70+ | | | | | | | | | | | X | X | +0.70 |
| | | | | | | | | | | | X | X | |
| 8 | | | | | | | | | | | X | X | 1 |
| 1 | | | | | | | | | | | X | X | 1 |
| 8 | | | | | | | | | | | X | X | 8 |
| 0.60+ | | | | | | | | | | | X | X | +0.60 |
| • | | | | | | | | | | | X | X | • |
| • | | | | | | | | | | | X | Ŷ | . • |
| 1 | | | | | | | | | | | x | X. | |
| 0.50+ | | | | | | | | | | | X | X. | +0.50 |
| 1 | | | | | | | | | | | X | X | 1 |
| | | | | | | | | | | | X | X | |
| 8 | | | | | | | | | | | X | X | |
| | | | | | | | | | | | X | X | 1 |
| 0.40+ | | | | | | | | | | | X | X | +0.40 |
| | | | | | | | | | | | X | X | • |
| : | | | | | | | | | | | X | X | : |
| | | | | | | | | | | | X | X | 3 |
| 0.30+ | | | | | | | | | | | X | x | +0.30 |
| | | | | | | | | | | | x | x | 1 |
| 2 | | | | | | | | | | | x | X | • |
| 1 | | | | | | | | | | | X | X | i |
| • | | | | | | | | | | | X | X | 3 |
| 0.20+ | | | | | | | | | | | X | X | +0.20 |
| | | | | | | | | | | | X | X | 1 |
| | | | | | | | | | | | X | X | : |
| • | XXX | | XXX | (XX | XX | XXX | | XXX | | XXX | X | X | |
| 1 | Ä | X | X | X | X | X | X | X | X | X | X | X | 1 |
| 0.10+ | X | X | ĭ | X | X | X | X | X | X | X | X | X | +0.10 |
| 3 | X | X X X X | X X X | X X X X | X X X | XXXXX | X X X X | X X X | X | X | X X X | X | |
| J | X | Ŷ | A Y | ¥ | A Y | A Y | X Y | X | X | X | Y | × | • |
| • | Ŷ | X | Ŷ | X | x | x | x | x | Ŷ | Ŷ | x | x | • |

| Bar | Exposure Condition | <u>Value</u> |
|--------|---|--------------------------------------|
| 129456 | Control 160°F, 90% R.H., 6 wks 12 wks 6 wks 12 wks 12 wks 230°F 6 wks | 0.14 0.13 0.14 0.13 0.71 |

The state of the s

Results:

 $\underline{\underline{\mathbf{D}}}$ Tensile Impact Test at Various Thermal & Moisture Exposures

Table Ten: Tensile Impact Strength

| Exposure Condition | | | Averag Streng | ged Tens: gth (ft | ile -lbs | Impact s./in²) | Δ from | Percent Control |
|--------------------|---------|------------|------------------|--|-------------|----------------|---------------|--------------------|
| Control | | | | 580 | | | | 0 |
| 160°F, 90% R.H., | 6 12 | | | 331 220 | | | | -42.9 -62.1 |
| 194°F | | wks wks | | 5 00 310 | | | | -13.8 -46.6 |
| 230°F | - | wks wks | | 13 brittle | to | test | | -97.8 |
| 266°F | 3 6 | wks wks | Too Too | brittle brittle brittle brittle | to to | test test | : | |

E Blocking Characteristics at Various Temperatures

Table Eleven

| | - |
|-----------------|--------------|
| Test Conditions | Test Results |
| -60°F | |
| after 1 day | no blocking |
| after 1 week | no blocking |
| after 1 month | no blocking |
| 73°F | ` |
| after 1 day | no blocking |
| after 1 week | no blocking |
| after 1 month | no blocking |
| 160°F | |
| after 1 day | no blocking |
| after 1 week | no blocking |
| after 1 month | no blocking |

Graph Ten

| | | Ť | H E | R | •• | | _ | | ı | ••• | • | • | S | ٠ | • | R | _ | | _ | X | • | 0 | • | • | R | _ | | | |
|-----|-------|---|-----|----|----------|---|-----|-----|---|-----|-----|----|---|---|----|-----|---|---|----|-----|----|---|---|----|----|---|---|----------|---|
| T E | N S I | | E | • | × | D | • | C | Ţ | s | T | • | E | | 8 | | н | , | - | | | | | ٠. | S | | , | IN * * 2 | , |
| 1 6 | 400+ | L | E | • | п | • | • | · | 1 | 9 | • | | E | | • | • | П | ` | • | • | • | _ | L | Đ | 9 | • | / | +600 | : |
| | 1 | | XXX | XX | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| | 540+ | | X | X | | | | | | | | | | | | | | | | | | | | | | | | +540 | |
| | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| | : | | X | X | | | | | | | | | | | | | | | | | | | | | | | | : | |
| | 1 | | X | X | | | | | | | | | | | XX | XX | K | | | | | | | | | | | : | |
| | 480+ | | X | X | | | | | | | | | | | X | , | K | | | | | | | | | | | +480 | |
| | 1 | | X | X | | | | | | | | | | | X | 2 | K | | | | | | | | | | | : | |
| | | | X | X | | | | | | | | | | | X | | K | | | | | | | | | | | : | |
| | : | | X | X | | | | | | | | | | | X | | K | | | | | | | | | | | • | |
| | 420+ | | X | X | | | | | | | | | | | X | | K | | | | | | | | | | | +420 | |
| | : | | X | X | | | | | | | | | | | X | 2 | X | | | | | | | | | | | : | |
| | : | | X | X | | | | | | | | | | | X | 7 | K | | | | | | | | | | ٠ | • | |
| | : | | X | X | | | | | | | | | | | X | 1 | X | | | | | | | | | | | 8 | |
| | 360+ | | X | X | | | | | | | | | | | X | 7 | X | | | | | | | | | | | +360 | |
| | 1 | | X | X | | | | | | | | | | | X | 2 | K | | | | | | | | | | | | |
| | , | | X | X | | 1 | (X) | (X) | (| | | | | | X | 1 | X | | | | | | | | | | | 8 | |
| | | | X | X | | 1 | (|) | l | | | | | | X | 1 | K | | X) | (X) | ľΧ | | | | | | | : | |
| | 300+ | | X | X | | 1 | (|) | (| | | | | | X | 1 | K | | X | | X | | | | | | | +300 | |
| | 1 | | X | X | | 1 | (|) | (| | | | | | X | 1 | K | | X | | X | | | | | | | 8 | |
| | 2 | | X | X | |) | (|) | [| | | | | | X | 7 | K | | X | | X | | | | | | | : | |
| | 3 | | X | X | |) | ſ |) | (| | | | | | X | 1 | K | | X | | X | | | | | | | 8 | |
| | 240+ | | X | X | | 1 | (|) | (| | | | | | X | 1 | K | | X | | X | | | | | | | +240 | |
| | | | X | X | | 1 | (| } | (| X | (X) | ΚX | | | X | 2 | K | | X | | X | | | | | | | : | |
| | 1 | | X | X | | , | (|) | (| X | | X | | | X | 2 | X | | X | | X | | | | | | | 1 | |
| | | | X | X | | } | (|) | l | X | | X | | | X | - 1 | X | | X | | X | | | | | | | | |
| | 180+ | | X | X | | 1 | K | 1 | (| X | | X | | | X | 1 | X | | X | | X | | | | | | | +180 | |
| | : | | X | X | | 1 | K | 1 | (| X | | X | | | X | 1 | K | | X | | X | | | | | | | 1 | |
| | | | X | X | | | K | 3 | (| X | | X | | | X | 1 | X | | X | | X | | | | | | | 3 | |
| | 1 | | X | X | | 1 | K | | (| X | | X | | | X | ; | X | | X | | X | | | | | | | 1 | |
| | 120+ | | X | X | | | ľ | | (| X | | X | | | X | 1 | K | | X | | X | | | | | | | +120 | |
| | | | X | X | | 1 | K | 1 | (| X | | X | | | X | 1 | X | | X | | X | | | | | • | | 1 | |
| | 1 | | X | X | | 1 | (| 1 | (| X | | X | | | X | 1 | X | | X | | X | | | | | | | 1 | |
| | | | X | X | | 1 | l | 3 | | X | | X | | | X | 1 | X | | X | | X | | | | | | | | |
| | 40+ | | X | X | | 1 | ľ | 1 | | X | | X | | | X | | X | | X | | X | | | | | | | + 60 | |
| | | | X | X | | 1 | ľ | 1 | | X | | X | | | X | | X | | X | | X | | | | | | | | |
| | 8 | | X | X | | 1 | K | 1 | | X | | X | | | X | | X | | X | | X | | | | | | | 1 | |
| | | | X | X | | 1 | l | 1 | l | X | | X | | | X | 1 | X | | X | | X | |) | ľΧ | XX | X | | | |
| | A - | | | | | | | | | | | | | | | | | | | _ | | _ | | _ | | | | _ ^ | |

| Bar | Exposure Condition | Value |
|-----|--|--------------------------|
| 123 | Control 160°F, 90° R.H., 6 wks 12 wks 194°F 6 wks | 580 331 220 500 |
| 5 | 12 wks | 310 |
| Ě | 230°F 6 wks | 13 |

Results:

 $\underline{\underline{\mathbf{F}}}$ Dimensional Changes at Various Conditions

Table Eleven

| Exposure Co | nditions | △ Percent Length | △ Percent Width |
|-------------|----------------------------------|-------------------|-----------------|
| 160°F, 90% | R.H., 6 wks | 0.0 | +0.1 |
| 194°F | 6 wks 12 wks | | -0.3 -0.6 |
| 230°F | 6 wks 12 wks | | -0.9 -0.9 |
| 266°F | 1 wk 3 wks 6 wks 12 wks | Too brittle to te | • |

Discussion:

The state of

The regular use of dental floss to remove interproximal plaque accumulation is an important factor in controlling dental disease. The dental tape studied in this project was felt to have several positive benefits in a mobile military environment.

To assure its stability under hostile environmental conditions, the coated elastomer ribbon was subjected to various thermal conditions. It was found acceptable for use in a temperature range of 0 to $120\,^{\circ}\mathrm{F}$. Due to high Modulus and low Tensile Impact Strength, the product will not function at -40 $^{\circ}\mathrm{F}$. Break Strength and Percent Elongation at breakage could not be accurately determined at $120\,^{\circ}\mathrm{F}$ due to limitation of the machinery used in the study.

The coated, elastomeric dental ribbon was found suitable for storage at 194 F and 160° F with 90% relative humidity for 12 weeks. Heat aging characteristics may be improved by the incorporation of an antioxidant upon extrusion of the tape.

Distribution List:

4.4

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